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UNEARTHING EARTHQUAKES IN THE SIENESE CRETE: HOW WE IMPROVED THE SEISMIC CATALOGUE OF A LOW-SEISMICITY AREA

Viviana CASTELLI[1] and Filippo BERNARDINI[2]

SUMMARY

The Val d'Orcia is one of the latest Italian entries (2004) of the UNESCO World Heritage List. Its distinctive landscape of rolling chalk hills (the Crete), shaped in the 14th and 15th centuries to reflect an idealized model of good governance, and celebrated in the paintings of the Sienese school, has become an icon of the Renaissance that profoundly influenced the development of landscape thinking worldwide. Preserving the cultural wealth embodied in this corner of Tuscany is also a matter of assessing its seismic hazard correctly. As a first step toward this end, we revised the local seismic history. According to the current national catalogue, the Crete are a low-seismicity area intervening between two earthquake clusters centered on Siena (north) and Mount Amiata (south); the local earthquakes on record are very few, with middle to low epicentral intensities and none earlier than the second half of 17th century. However, the fortuitous discovery of a recent (1802) damaging earthquake unrecorded by any of the extant catalogues suggested that the current interpretation was more likely to derive from the little interest shown in the area having by previous studies rather than from an actual lack of data. By retrieving the memory of several forgotten damaging earthquakes (from 1449 onwards) and increasing the data set of the already known events, our study does significantly improve the Crete seismic history.

1. INTRODUCTION

The area called - from its distinctive clay hills and plains - Le Crete Senesi or "Sienese Clays" occupies three valleys (Val d'Arbia, Val d'Asso and Val d'Orcia) placed south-east of Siena and north of Monte Amiata, the divide between Tuscany and Latium. Through Le Crete runs the ancient Cassia/Francigena road, linking Rome with northern Italy and France, which in the Middle Ages brought great prosperity to Siena. Wealthy Sienese landowners contributed to shape the more fertile parts of the area – especially Val d'Orcia, known as one of the best wine-countries of Italy from the early 1500's – as an embodiment of their city-republic's ideal of bourgeois "good governance" immortalized by the medieval Sienese painters; the less promising bits were used for extensively growing wheat or grazing sheep. In Le Crete there was space enough for almost any cultural experience, from the 14th century heremitic utopia of Monte Oliveto Maggiore to the 15th century urban planning of Pope Pius II, who built from scratch an ideal Renaissance town (Pienza). Later, the devastating war which led to the fall of the Sienese republic (1552-1559), the following economic slump and sharp changes in cultural and agricultural tastes would turn Le Crete into a depopulated and impoverished backwater "...as bare and desolate as any Scottish moors...as barren, as stony, and as wild, as Cornwall in England" [Dickens, 1846], a region to be shunned rather than sought. It took the vision and dedication of a few enlightened late 19th and early 20th century groundbreakers – such as the Biondi-Santi and Origo families [Origo, 1970] – to turn the tables back again. It is to them that Le Crete owe their present unparalleled, worldwide prestige as icon of civilized beauty and harmonious landscaping, reflected in the inclusion of two local sites – the town of Pienza and the whole of

[1] *Istituto Nazionale di Geofisica e Vulcanologia (INGV), Sezione di Bologna, Sede di Ancona, at Protezione Civile Regione Marche, Contrada Passo Varano 1, 60029 Varano (AN), Italy*
Email: castelli@mi.ingv.it
[2] *Istituto Nazionale di Geofisica e Vulcanologia (INGV), Sezione di Bologna, via Donato Creti 12, 40128 Bologna, Italy*
Email: bernardini@bo.ingv.it

Val d'Orcia – in the UNESCO World Heritage List. Preserving the cultural patrimony embodied in this corner of Tuscany is also a matter of assessing its seismic hazard correctly. As a first step toward this end, we considered the meagre local seismic history, as recorded in the latest Italian catalogue [CPTI Working Group, 2004], trying to understand how much representative it is and how it could be improved.

2. THE SEISMICITY OF LE CRETE ACCORDING TO THE CURRENT CATALOGUE

According to the current national catalogue [CPTI Working Group, 2004] Le Crete are a low-seismicity area placed between two earthquake clusters centered respectively on Siena (north) and Mount Amiata (south) (Figure 1).

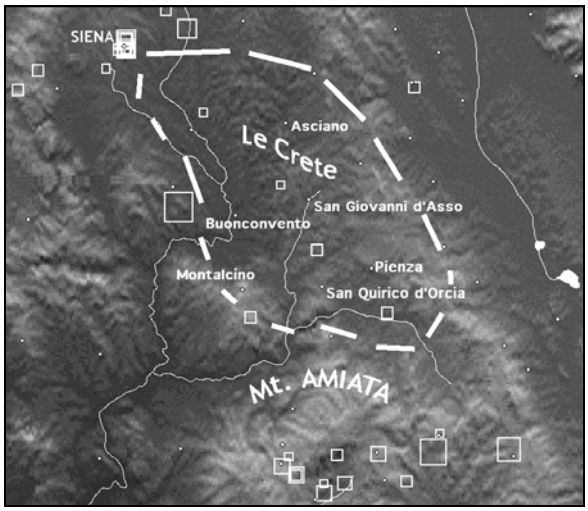

Figure 1: "Le Crete" area in the frame of the regional seismicity; white, empty squares represent the earthquake epicenters listed in the latest Italian catalogue [CPTI Working Group, 2004]

There are very few local earthquakes on record (Table 1), none earlier than the second half of 17th century and most with modest epicentral intensities. The notable exception is the 1909 Murlo earthquake (Io VII/VIII MCS; Maw 5.4 [CPTI Working Group, 2004]), that is "local" insofar as the village of Murlo is placed on the outskirts of Le Crete, but whose higher effects occurred in a much wider area than Le Crete; this earthquake seems to have been a one-off among Le Crete earthquakes, as far as present knowledge goes.

Table 1: Known historical earthquakes of the Sienese Crete area [CPTI Working Group, 2004]

Date	Epicentral area	Available study	Macroseismic data points	Io (MCS)	Maw
1679 03 24	SIENA	Preliminary	2	V-VI	4.6
1726 04 09	MONTE OLIVETO	Preliminary	2	V-VI	4.6
1780 01 03	MONTE OLIVETO	Preliminary	1	V-VI	4.6
1897 11 15	PIENZA	None	-	VI	4.8
1909 08 25	MURLO	Advanced	283	VII-VIII	5.4
1947 12 24	S.GIOVANNI	None	-	VI	4.8

Is this all there is to know about Le Crete historical seismicity? Maybe not: the existence of at least one more local earthquake (1802) came accidentally to light a few years ago, when a sheaf of letters describing it was discovered among the records of the relevant Siena earthquake of 26 May 1798 preserved at the State Archive of

Siena, after having been mistakenly filed [ASSI, 1802]. This fortuitous discovery of a recent – and damaging – earthquake totally unknown to any of the extant Italian catalogues, suggests that: a) current knowledge on local seismicity is certainly incomplete and it is at least possible that more such cases are still waiting for discovery; b) as local earthquakes seem to be not lacking, their absence from the current catalogues is likely to derive from a defectiveness of the sources from which the catalogues drew their information.

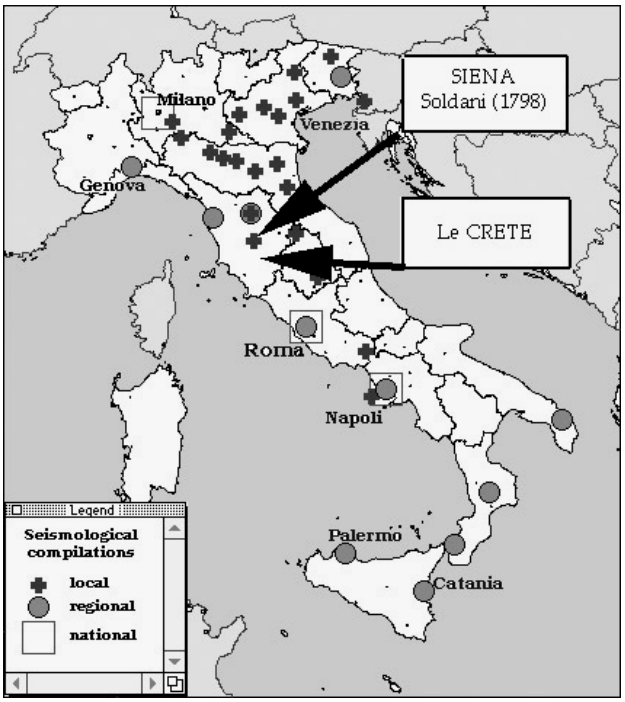

Figure 2: Italian earthquake compilations and their outlook (see text)

The bulk of earthquake records included in the modern Italian parametric catalogues was originally derived from a large corpus of descriptive earthquake compilations, mostly written in the 17th-19th centuries, some with a national outlook, others with a regional or even a local one (Figure 2). Among them, the main source of earthquake information on Siena and southern Tuscany was Soldani [1798], a compilation mostly focused on Siena itself, and the source of information on the few earthquakes earlier than 1798 to be found in Table 1, information on those later than that date being derived from contemporary seismological bulletins.

3. THE SEARCH

The working hypothesis adopted by this study is that a possible reason for the little number of Crete earthquakes to be found in the current catalogue (especially before the 1870's, i.e. during the pre-bulletins era) is the narrow outlook of the main source to which the identification of these same earthquake is originally due, namely Soldani [1798]. The main purpose of this study has been, a) to find ways to check whether any more "lost" local earthquakes (lost to the current Italian catalogues, that is) could be quickly and expeditiously identified and, b) in case any were actually found, to gather for each of them as much original evidence as possible on a next-to-nothing budget. A secondary goal was to improve the information available on those among the earthquakes listed in Table 1 for which only a preliminary study (or no study at all) was available. Lost earthquakes were looked for by examining a large sample of likely "collectors of written evidence" on the Crete area, whose unifying feature was not having been previously considered by earthquake compilations and/or parametric earthquake catalogues. They included standard reference works for the area [Repetti, 1834-1837; Cammarosano and Passeri, 1985], local historical studies, magazines and guidebooks, scientific literature (such as Liberati [1898], Forlani Conti [1982]) and the preliminary results of ongoing studies of European early journalistic sources (described in Camassi and Castelli [2004]) and Tuscan private journals. The same kind of bibliography was used to advance the study of the earthquakes listed in Table 1.

4. CASE-HISTORIES

The present results of this study allow at least four more damaging earthquakes (the earliest of which occurred in 1449) to be added to the Sienese Crete seismic record, as presented in the CPTI Working Group [2004] catalogue. It was also possible to improve the macroseismic databases available for the earthquakes already listed by CPTI Working Group [2004]. The epicentral parameters of all the events involved will have to be assessed (or re-assessed), taking into account the new data. Short notes on the present-day state of information on the studied earthquakes follow here below:

4.1 1449 October 16 – Asciano

Unlisted by seismic catalogues. The ramparts of the small town of Asciano suffered widespread damage, their crenellations being destroyed. This could have been partly due to a preexisting state of bad repair, as pointed out by a contemporary letter from the Asciano community to the Sienese government [ASSI, 1443-1450]. According to the contemporary chronicle by Tommaso Fecini [15th century], it was strongly felt in Siena.
A recent study [Alessi, 2002] suggests that the same earthquake could have been responsible for severely damaging the Corboli palazzo, one of the most outstanding private buildings of Asciano, which shows traces of extensive, post 14th century restoration.
On the basis of such pieces of information, we believe that this earthquake caused significant damage to Asciano (VII MCS) and reached intensity V MCS at Siena.

4.2 1498 April 11 – Siena-Pienza

Unlisted by seismic catalogues. According to the contemporary Sienese chronicler Tizio [15th-16th century] this earthquake, occurred on Holy Wednesday, during the Mass, caused slight damage to the Cathedral of Siena and heavier damage to the Cathedral of Pienza, in Val d'Orcia. The latter was built (in 1459), partly on stable ground and partly (the apse) on an unstable clay cliff, a situation which lead to the development of cracks in the walls even before the construction was completed and from which a long history of periodical stabilizing interventions has followed [Forlani Conti, 1992]. Therefore, earthquake effects gauged only on this specific building could be less than reliable as an indicator of the level of effects reached in the whole town.

4.3 1545 November 16 – Sienese countryside

Unlisted by seismic catalogues. Intensity map shown in Figure 3. Recorded by eyewitnesses in Siena, Pienza and Fratta. Highest effects reputedly occurred "In Upper Val di Chiana and Val d'Asso" [Manuscript Note, 16th century], though there are no precise descriptions of damage from this area. In Pienza there was heavy damage ("ruins") to private buildings and a partial collapse of the roof and belltower of the Cathedral [Vannucci, 16th century]. Private buildings in S. Quirico d'Orcia suffered heavy damage too [Bardi, 16th century]. Felt in Siena and Fratta. Vincenzo Vannucci [16th century], who was a child at the time, describes a fissure that appeared in the ground in that occasion and which "goes from the church of St Catherine down to the Ciglio Gate", and that could perhaps be interpreted as evidence of surface faulting in Pienza.

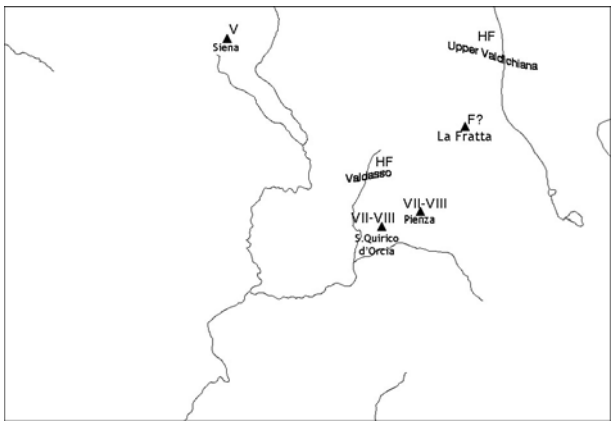

Figure 3: Intensity map of the November 16, 1545 earthquake. Intensity data (MCS) from this study (HF=Heavily Felt; F=Felt)

4.4 1679 March 24– Val d'Orcia (?)

Listed by seismic catalogues as a minor event (Io V-VI MCS, Maw 4.6; [CPTI Working Group, 2004]) felt in Siena and at the abbey of Monte Oliveto Maggiore, near Asciano [Soldani, 1798]. According to a contemporary newsletter quoted in Ghiselli [18th century], though this earthquake caused no damage to buildings, "several people" suffered injuries owing to it (panic-induced injuries? Heart attacks?). The municipal records [Spogli ..., 1608-1692] of Montepulciano, a town placed at a short distance from Le Crete proper, give evidence that, at the beginning of May 1679, measures were being taken for the restoration of some municipally-owned buildings which had been "devastated by the earthquake". It is at least possible that the earthquake felt in Siena and Monte Oliveto Maggiore on March 24 was the same event that caused the damage on record in Montepulciano. From such a perspective, the earthquake of 1679 March 24 might have resulted in the macroseismic scenario depicted in Figure 4.

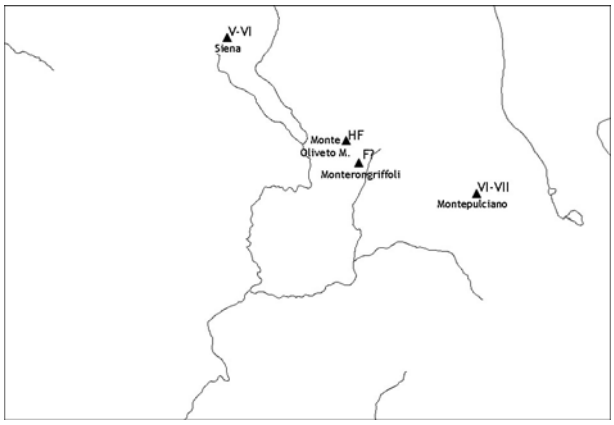

Figure 4: Intensity map of the March 24, 1679 earthquake. Intensity data (MCS) from this study

4.5 1726 April 19 – Monte Oliveto Maggiore

Listed by seismic catalogues as a minor event (Io V-VI MCS, Maw 4.6; [CPTI Working Group, 2004]) that caused slight damage in Siena, to the abbey of Monte Oliveto Maggiore, and generally "everywhere in Le Crete" [Soldani, 1798]. A contemporary Sienese diarist [Pecci and Pecci, 18th century] expatiates a bit more on the level of damage in Siena ("a few fallen chimneys and stones") but, for the time being, no evidence has been found on which sites in Le Crete could have been damaged apart from Monte Oliveto Maggiore (where the vaulted roof of the abbatial Pharmacy collapsed). A letter written in 1781 (see following paragraph) by the abbey Cellarer [AMOM, 1781c]; according to this source "around 1722 an(other) earthquake caused ruins in Roffeno (now Badia a Rofeno)". Making allowance for the understandable fogging up of memory due to an interval of almost sixty years between the related fact and the letter, it is likely that the cellarer was speaking of the 1726 event and that Badia a Rofeno was another of the sites it affected.

4.6 1781 January 3 – Monte Oliveto Maggiore

Listed by seismic catalogues as a minor event (Io V-VI MCS, Maw 4.6; [CPTI Working Group, 2004]) that was felt in Siena and damaged the abbey buildings of Monte Oliveto Maggiore on January 3, 1780, possibly because of a misprint, as both the original source for this listing [Della Valle, 1781] and other Sienese sources [Gazzetta Toscana, 1781; Pecci and Pecci, 18th century; Soldani, 1798) clearly give the date of this earthquake as January 3, 1781. First-hand information on the effects in the Crete area is available in the Monte Oliveto Maggiore archives [AMOM, 1781a-b-c; Donghi, 1992], where some letters and a detailed damage survey give damage descriptions for the abbey buildings, the nearby village of Chiusure, and smaller rural settlements (Avena, Bollano, Colombaio, Roffeno etc.). The Gazzetta Toscana [1781] also mentions damage to "the villa of Signor M.A. Borghesi in those surroundings", a likely reference to the village of Monterongriffoli [Repetti, 1834-1837]. The earthquake was heavily felt in Buonconvento [AASI, 18th century], Sinalunga, Montepulciano, Pienza, Montalcino and Santa Fiora [Gazzetta Toscana, 1781], and finally in Arezzo [Albergotti, 18th-19th century]. Intensity map shown in Figure 5.

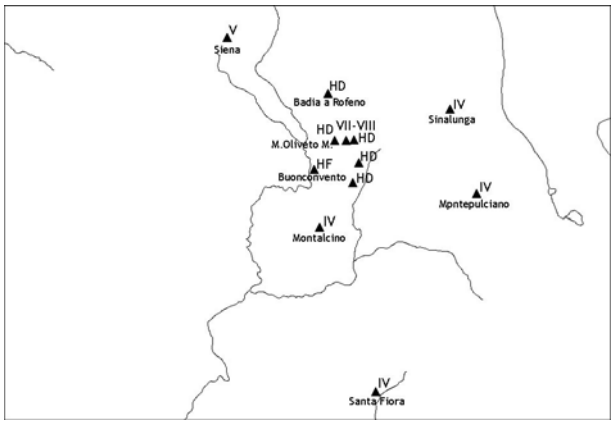

Figure 5: Intensity map of the January 3, 1781 earthquake. Intensity data (MCS) from this study (HD= Heavy Damage; HF=Heavily Felt)

4.7 1798 September 8 – Val d'Orcia

Unlisted by seismic catalogues. Recorded by the Gazzetta toscana [1798] as having caused "some damage in Montalcino and surroundings" and having been felt in Siena and Montepulciano. It is likely that the Cathedral of Pienza was also damaged by this earthquake, as a damage survey dated on August 19, 1800 and evaluating "the damage wrought by the earthquakes and the slipping down of the building" is preserved in the Opera del Duomo of Pienza archives [Forlani Conti, 1992].

4.8 1802 October 31

Unlisted by seismic catalogues. Intensity map shown in Figure 6. Information on this earthquake comes from a file preserved at the State Archive of Siena [ASSI, 1802] and including several letters, reports and damage surveys sent from government officers of Montalcino, Pienza and S.Quirico d'Orcia to the Governor of Siena. The heaviest damage occurred in the village of Torrenieri (VII MCS) and in several nearby small rural settlements (some of which have still to be identified). In one of the latter, the collapse of a chimney caused the death of some people sitting around a fireplace. Lesser damage (VI MCS) occurred in Montalcino [Gazzetta Toscana, 1802], S.Quirico d'Orcia and Pienza: in the latter town the most heavily damaged building was, once more, the Cathedral, for which a new damage survey had to be made [Forlani Conti, 1992], but two public buildings and nine private houses suffered slightly too [ASSI, 1802]. A Sienese diarist [Bandini, 18th-19th century] gives a list of places where this earthquake was felt (Siena, Asciano, Monte Oliveto Maggiore, Monticchiello, Radicofani).

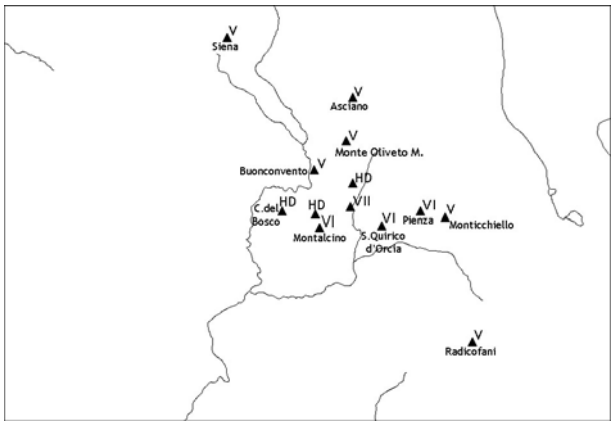

Figure 6: Intensity map of the October 31, 1802 earthquake. Intensity data (MCS) from this study (HD= Heavy Damage)

4.9 1947 December 24

Listed by Italian seismic catalogues as a minor event in the area of San Giovanni d'Asso (Io VI MCS, Maw 4.8 [CPTI Working Group, 2004]). However, no study has been carried out on this earthquake so far, nor macroseismic data are available yet (see Table 1).
Detailed information on the effects caused by the main event are reported by Agamennone [1943-1948], who collected 26 reports sent to the "Ufficio Centrale di Meteorologia e Geofisica" (UCMG, the Royal Central Office of Meteorology and Geophysics in Rome) by several localities of the Siena Province. Seventeeen of these reports describe effects observed in eighteen sites where the earthquake was felt and - in a few cases - caused some damage as well; another nine reports account for the earthquake not having been felt in as many localities.
The most severe effects were observed in the area stretching between the Val d'Asso and the Val d'Orcia. The small towns of S. Quirico d'Orcia, San Giovanni d'Asso and Pienza were slightly damaged (VI MCS): some chemneys and flakes of plaster fell down, minor cracks opened in some old buildings; small items were knocked down from shelves and people fled from their homes in panic; in S. Quirico d'Orcia some stones fell from the ancient walls of the town, and the ceiling collapsed in a house. In Pienza a crack opened in the choir of the Cathedral and a dwelling was left unfit for habitation.
The earthquake was felt strongly (IV-V to V MCS) in Buonconvento, San Casciano dei Bagni and Asciano, and with slight-to-moderate intensity (III to IV MCS) in Montalcino, Montepulciano, Murlo, Sarteano, Sinalunga, Trequanda, Abbadia San Salvatore, Rapolano Terme, Monticiano, Piancastagnaio and Torrenieri; it is attested as not felt in Casole d'Elsa, Chiusi, Gaiole in Chianti, Poggibonsi, Radicofani, Radicondoli, San Gimignano and Sovicille. Intensity map shown in Figure 7.

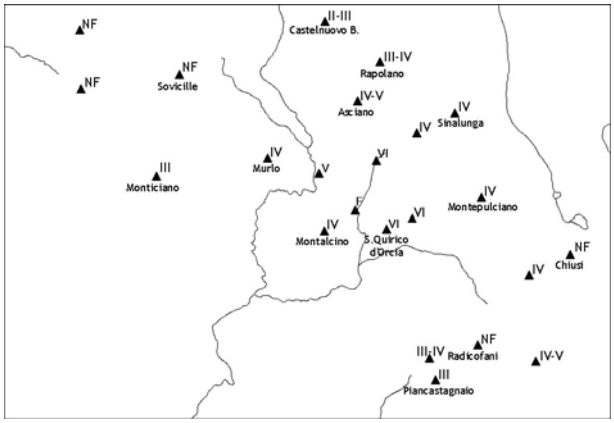

Figure 7: Intensity map of the December 24, 1947 earthquake. Intensity data (MCS) from this study (F= Felt; NF=Not Felt)

5. CONCLUSION

The local seismic history of "Le Crete Senesi" has been revised. Information on nine comparatively minor damaging earthquakes has been collected and critically analysed. Five out of nine of them (occurred on October 16, 1449; April 11, 1498; November 16, 1545; September 8, 1798 and October 31, 1802) are not listed by any of the current Italian seismic catalogues. For another four earthquakes, already listed by Italian seismic catalogues, new information has been collected which allows to improve our knowledge of their effects and delineating, in a couple of cases, a more severe scenario than it was previously thought. In all, the results of this study sensibly improve our perception of the actual seismicity of "Le Crete Senesi", an area previously believed to be only sporadically affected by a very low level of seismic activity. The "new" historical data now made available to point out that, at least from the mid-1400's onwards, damaging earthquakes that it is fair to define "minor" only insofar as their major effects occurred in a comparatively narrow compass, occurred more frequently than it was previously believed. The level of earthquake damage likely to affect Le Crete Senesi is certainly lower than it can be expected in other parts of Italy but it certainly poses no lesser problems, as even "minor" damaging earthquakes - such as can undoubtedly be expected to occur in this area - would represent a serious threat for the precious cultural patrimony embodied in this corner of Tuscany.

6. ACKNOWLEDGMENTS

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